ORIGINAL ARTICLE

EFFECT ON HARDNESS OF REUSED CAST COBALT CHROME ALLOY USING FLAME CENTRIFUGE CASTING METHOD

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ABSTRACT

In dentistry lost wax casting method requires more alloy than needed to produce indirect restoration. The surplus casting alloy is re-used in routine. The aim of the present study was to assess the micro-hardness of the commercially available Cobalt-Chromium alloy, when 50 wt. % re-used alloy is added to it; up till six times. The study sample was divided into four groups (n=5). Group 1 was the control group with 100% fresh alloy cast once. In group 2, 3 and 4, a 50 wt.% cut off of previous castings were mixed to the fresh alloy. All the samples were cast using oxy-acetyl flame with broken arm centrifuge casting method. The hardness measurements were carried out under 500 gram force load for 10 second (ASTM-E 384) using micro hardness tester: Model: HVS-1000. Three indents were made on each specimen. The means of micro-hardness in study groups were compared using one-way ANOVA. The group1 had the maximum mean hardness (340+10); followed by group 2 with 305+11; group 3 had 334+10 and group 4 had the least hardness 303+15. F-test was non-significant at 5% level of significance (p-value=0.094) suggesting there was no difference among the hardness of the four groups.

Key Words: *Cobalt Chromium Alloy, Hardness, Reuse*

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INTRODUCTION

Chromium alloys belong to the super alloys class that enjoy wide application in dentistry ranging from dental implants, cast prosthesis, orthodontic wires to surgical screws and plates.[1] Initially these hard alloys were introduced as an economical replacement for cast gold with near comparable biocompatibility but even better physical properties more suitable for cast prosthesis and long span bridges. These mechanical properties include high hardness (350-370 HV), higher yield strength and fatigue resistance (700-850 MPa), sufficient tensile strength (6-10%) and sag resistance.[2] These hard alloy's high modules of elasticity render them sufficient strength at thin cross sections, making the large prosthesis more acceptable due to lighter weight. Any changes in alloy properties like hardness intern denotes a change in other properties such as wear resistance or tensile strength. An unexpected increased hardness might lead to unwanted enamel abrasion while a decrease depicts a compromised strength.[3]

Hardness itself is not a fundamental property, for its value depends on various physical properties like yield strength, tensile strength and modulus of elasticity. Thus a test of material hardness can predict an alloys property such as yield strength and wear behavior in service. [4] It is also used for alloy quality monitoring during processing. [5]

In dentistry cast alloys are processed through lost wax casting method that requires more alloy than needed to produce a restoration. [6] The surplus metal like the crucible former and sprue area of the casting fall under the process scrap category. [7] The alloy waste produced in field of dentistry are clean as alloy is processed under a controlled environment and rarely

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requires any chemical treatment. Re-use of such alloy is a routine practice.[8] There have been studies on the re-use of alloys but a controversy exists regarding proportioning of fresh alloy to once use alloy and the number of time an alloy can be reused.[9]

The present study was done to access the micro-hardness of the commercially available Cobalt-Chromium alloy, when 50 wt. % re-used alloy is added to it; up till six times. According to the null hypothesis, the micro-hardness value of the Co-Cr alloy will not be affected by the addition of 50wt. % re-use alloy to the 50 wt. % fresh alloy.

MATERIALS AND METHODS

In the present in-vitro experimental study a commercially available Cobalt Chromium alloy with composition Co 64 · Cr 28.6 · Mo 5 · Si 1 · Mn, C each < 1 (Wironit Bego Germany; ISO 22674) was re-cast in a fix ratio of 50 wt. %, for six times.

The study sample was divided into four groups (n=5) such that group 1 was the control group with 100% fresh alloy cast once. In the intervention group 2, 3 and 4, a 50 wt.% cut off of previous castings were mixed to the fresh alloy. The wax pattern was made using 4mm diameter round sprue former wax (Bego, Germany. ref 40088), attached to the rubber crucible former making a total length of 25mm. For each casting 300 grams phosphate bonded investment powder (Willavest powder; Bego, Germany) and 39ml liquid (with 20% water dilution) was mixed in a vacuum mixer (Tornado silfradent 804, Italy) according to the manufacturer instructions. The investment was poured in the casting ring on the vibrator at minimum speed. After 10 min of initial set, the crucible former and the disposable card casting ring were removed.

The wax burn out was carried out in ceramic furnace, started at room temperature and raised to 250◦C at 5°C/min rate. After 30 min duel the mould was heated to the final temperature of 950◦C at 7◦C/min and heat soaked for further 30 min. The total time taken for one casting was 2hr and 30minutes.

Four fresh alloy ingots of Wironit (Bego Germany ref 50030) were used for group 1. Oxy- acetyl flame was used for alloy melting with the torch tip kept at 15-25 mm from alloy. Flame was adjusted, with the flow pressure of acetylene set at 0.5 bars and 2.0 bars for oxygen. The blue inner cone of the flame was used for alloy melting by light rotating movement. Investment mould was taken out of the furnace and placed in the cradle of the casting machine. The molten alloy was centrifugally cast under spring load of minimum three turns. [10] The mould after casting was allowed to cool down to the room temperature.

After bench cooling the divestment and cleaning was done with a ¼ round tungsten carbide and a fissure diamond burr .The castings were air particle abraded (50 micrometer aluminum oxide, Korox; Bego, Germany). The metal sprue area was removed using cutting discs. These cutoffs were used for further group castings. Each button was cut and weighed equal to two pre-weight fresh ingots of Wironit (approx 6 gm each).

The re-used alloy for the group 2 and 3 was further aged or exposed to casting separately. All the samples were cast using oxy-acetyl flame with broken arm centrifuge casting method. The cast samples, five in each group were embedded in one mould of auto-cure acrylic resin. The embedded specimens were recovered and ground flat using belt emery paper starting from grad 240 up till 2400 on grinding machine (TwinPrep 3TM: Allied High Tech product inc.). Final polishing was done with slurry of various gradations of diamond past (Ranging from 6, 3, 1 and 0.25 microns) to achieve a uniform scratch free surface with a mirror finish. [11] Specimens were cleaned with ethanol then mounted on micro hardness tester: Model: HVS-1000. A diamond shaped, square based pyramid indenter was used. The angle between the faces of pyramid was 136^o. The hardness measurements were carried under 500 gram force load for 10 second (ASTM-E 384). [12] Micro Vicker's hardness number was calculated by measuring the length of the diagonals of the indentation and averaged, the hardness number was obtained from the digital output of the machine. Three indents were made on each specimen. Indents were visible under 30X magnification. In case of a non symmetrical indent, an extra reading was taken by substitution indents.

RESULTS

As a whole a wide range of variability in the micro Vicker's hardness values was observed. In group 1 the Vicker's hardness value ranged from 297.82HV to 353.33HV. Group 2 being the first intervention group showed hardness value ranging from 309.52 to 398.26 HV. For group 3 micro-hardness values ranged from 269.67HV to 328.13HV while for group 4 its value ranged from 271.79 to 357.06 HV (figure 1).

Thus the mean values of group 4 was the lowest. The total mean micro Vicker's hardness of the alloy in the four groups was 321.21HV.

While comparing the hardness values of alloy considered in the four different groups the data was analysed by one-way ANOVA (Table 1). The F-test was non-significant at 5% level of significance (p-value=0.094) suggesting there is no difference among the hardness of the four groups.

Least Significant Difference (LSD) test was applied

TABLE 1: STATISTICAL ANALYSIS OF MICRO VICKER'S HARDNESS NO.(VH) OF ALL THE CAST COBALT CHROMIUM ALLOY GROUPS (ANOVA).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5646.487	3	1882.162	2.528	.094
Within Groups	11911.381	16	744.461		
Total	17557.868	19			

TABLE 2: STATISTICAL MULTIPLE COMPARISONS OF THE MEANS (LSD): MICRO VICKER'S HARDNESS (VH) OF CONTROL GROUP (1) WITH INTERVENTION GROUPS (2, 3 AND 4).

Main Group(i)	Comparison Groups (j)	Mean Difference (i-j)	Std. Error	Sig.
G-1 ONE time cast Cobalt Chromium Alloy (Control Group:100% fresh alloy)	2	5.884	17.256	.738
	3	35.26	17.256	.058
	4	37.25	17.256	.046
G-2 TWO times cast Cobalt Chromium Alloy (Intervention Group:50% fresh alloy + 50% cut off of G1)	3	-29.38	17.256	.108
	4	1.98	17.256	.910
G-3 FOUR time cast Cobalt Chromium Alloy (Intervention Group:50% fresh alloy + 50% cut off of aged G2)	4	31.36	17.256	.088

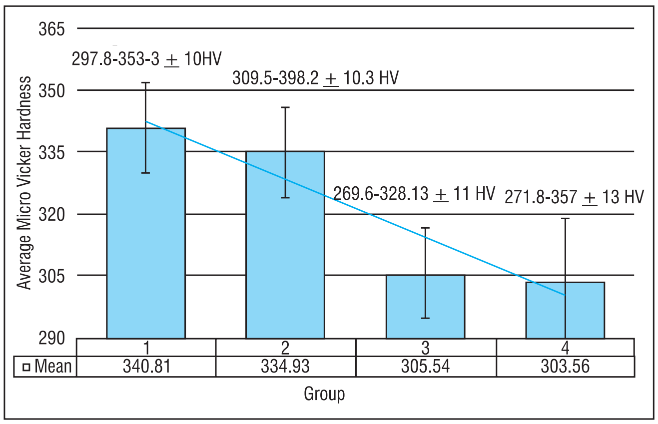

Fig 1: Micro Vicker's hardness values (HV) of cast Cobalt-Chromium alloy in group1, 2, 3 and 4.

and the results are shown in Table 2. The only pair showing the difference (0.046) at 5% level of significance was group1 with group 4. But the significance level was low.

Thus we fail to reject the null hypothesis of the present study.

DISSCUSION

Among the indirect restorations made in dental laboratories, the quantity of the scrap alloy produced during the fabrication of removable partial dentures is quite large. [13] Reusing alloy for such restorations is a routine procedure. Especially for under developed countries with limited resources. [14]

The present study protocol of 50wt% reused alloy addition to the fresh alloy is supported by Corroy's literature review. Their review emphasised on adapting a general consensus on reuse protocol that is easy and cost effective with straight forward evaluation methods outlined to help validate reuse of alloy. Alloys, specially the base metal alloys are heterogeneous in structure with phases having varying properties. Micro Vicker's hardness test is recommended for such alloys (ASTM-92). [15]

In the present study; statistically, under the testing conditions there was less significant difference in the micro hardness of the alloy in the four groups. Group 1 Vicker's hardness value (mean 340.8 HV) was closest to the manufacturer claim (350 HV). The overall mean micro Vicker's hardness value of all the groups throughout the experiment was 321.21 HV. This difference was statistically found insignificant. In agreement to the present study finding; studies support alloy re-used if fresh alloy is added to maintain its properties. [16-20] Even though Gupta and Mehta advocated a 50wt% fresh alloy addition to the used alloy on fourth recast and also observed an overall reduction in micro hardness value of alloy when recast. Contrarily reported statistically significant changes while comparing hardness values of once melt Co-Cr alloy (373 HV) with three and four time induction cast alloy (346 HV). [21] This decrease was progressively noted in all the intervention groups.

Study conducted by Nelson et al on hardness of recast alloy from first through fourth generations showed no significant difference. In agreement to the present study, their values were also not consistent among the four generations. But unlike the present study, the results of Micro Vicker's hardness test exceeded the calculated minimum specification for the alloy (335VH to 390VH). [22]

Al-Ali while comparing Co-Cr alloy of two different manufacturers (Remanium, Dentaurum, Germany and Biozil, Degussa, Germany), reported a significant increase in hardness with 100% and 50% recast alloy. They reasoned, the increased hardness to be contributed by an increase in carbon content of alloy due to conventional casting procedure. [23]

The variations in the values of micro hardness obtained in the present experimental trial can be explained by studies done by Kaiser [24] and Vitovec [25]. According to Kaiser, the conventional indentation tests provide values indicative of the overall matrix of the alloy. In an alloy system the dimensions of features like the grains, carbon at the grain boundaries and inter granular matrix or micro pores caused by alloy shrinkage are quite variable. The indenter may exceed the depth of the feature (like grains), thus under estimating the hardness.[24]

Vitovec detailed micro hardness values obtained by test loads less than 1000 grams show a low hardness value than the expected or actual value contributed by work harden surface of the heterogeneous alloy. [25]

Li in his work on recasting protocol proposed particle abrasion followed by immersion in aqua regia for 15 minutes for Co-Cr alloy. [26] Whereas in the present study acceptable results were obtained by only particle abrasion method. No hazardous chemicals were used.

It is recommended that in order to avoid random mixing of old and fresh alloy, a simple straight forward proportioning of 50wt. % of alloy will help establish an empirical formula which can be easily managed and followed by the local laboratories.

Thus the present study proportioning method (i.e. 50% by weight addition of both the fresh and re-use alloy) will be helpful in setting an empirical relation for recasting alloys till six times.

CONCLUSION

Within the limitation of this study, on the basis of Micro Vicker's hardness values, Cobalt-Chromium-Molybdenum alloy can be re-used till six times provided a 50% fresh alloy is added to it on each recast, without changing the properties of the alloy.

LIMITATIONS AND RECOMMENDATIONS

Since re-casting is carried out for economic and ecological reasons, a further increase in the percentage of re-use alloy to fresh or further re-castings (more than six times) should be carried out till a significant difference can be noticed.

Using the present study protocol a detailed analyses for explanation of the present study observation are recommended. Effects of element release and cyto-toxicity along with microscopy of the re-used alloy for their clinical applicability should be carried out. Other mechanical properties important for cast partial dentures like flexural strength should also be tested.

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